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# Renewable energy market conditions and barriers in Turkey

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ABSTRACT

Decentralized wind, hydropower, biogas and biomass, geothermal, solar thermal and solar electricity energy systems are the most commonly found renewable energy technologies promoted for rural energy supply within sustainable developments programs. They are, therefore, seen to have a central place in the practice of sustainable development and in allowing less development countries to bypass the environmentally damaging fossil fuel intensive paths made by industrialized countries. On the political front, many less development countries are critical of pressure on them to adopt environmental energy technologies.

Turkey is situated the meeting point of three continents (Asia, Europe and Africa) and stands as a bridge between Asia and Europe. The country is located in southeastern Europe and southwestern Asia. As Turkey's economy has expanded in recent years, the consumption of primary energy has increased. Presently in order to increase the energy production from domestic energy resources, decrease the use of fossil fuels as well as reduce of green house gas emissions different renewable energy sources are used for energy production in Turkey. The share of energy production from renewable energy sources has increased during the last 10 years. Turkey must import most of the energy to meet her needs. Turkey also has a large potential for renewable energies. The lack of knowledge about renewable energy technologies by most policy-makers, potential consumers, and energy firm managers has played against renewable energy developments. The paper presents renewable energy used in Turkey and Europe Union and evaluation of the market conditions and barriers of renewable energy use in Turkey.



**Contents**



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## 1. Introduction

Energy is one of the most important inputs in the process of development. Although extensive studies on energy production and consumption of industrialized countries exist, studies concerning energy in developing nations, especially taking into account the importance and place of traditional fuels, have either not been made or have begun only recently. Since energy shortcomings promise to have serious economic, political and social consequences, energy planning should constitute the most important aspect of overall development planning in developing countries. In the light of the proposed transition to a low carbon energy market, the role of future energy sources depends on, amongst other factors, their cost, technical potential for capacity, availability of good sites and the need for energy storage or load matching [1].

Renewable energies are an important factor for the strengthening of the regional development. However, there are many challenges facing the efforts to increase renewable energy use, which have to be understood and properly translated into a comprehensive regulatory framework. The first and foremost barrier for higher renewable energy penetration into energy systems lies in their high-up front costs and related insufficient cost effectiveness. Thus, it is necessary to introduce financial support mechanism and favorable promotion schemes, especially ones that will attract private financing into energy sector and in such manner reduce the financial burden on the state budget [2].

Turkey, an energy-importing developing country, presently depends heavily on imported petroleum. The increases in international petroleum prices have affected the Turkish economy adversely, and promise to be the same in the future unless dependence on imported petroleum is reduced by substituting other resources for petroleum. Taking into account the degree of the present Turkish economic development and the level of industrialization attained, and the direction Turkish economy is heading in general, electricity from nuclear power plants, along with the development and use of other energy resources, is found to be the most suitable substitute in this study. This is in contradiction with the present official policy of utilizing domestic lignite and hydro resources. There are many different types of renewable energy that in the longer term should be capable of being harvested to provide a more sustainable energy future. The principal renewable forms of energy are listed in Table 1, together with their category and likely time-scale of early commercial use.

**Table 1**
Renewable energy sources and means of utilization [3]

| Energy sources | Energy form | Availability |
|---|---|---|
| Agriculture and forestry waste | Combustion process | Now |
| Energy crops | Combustion process | Now |
| Landfill and sewage gas | Combustion process | Now |
| Municipal solid waste | Combustion process | Now |
| Direct solar (active and passive) | Heating | Now |
| Geothermal | Heating/electricity | Now/limited scope |
| Hydropower | Electricity | Now |
| Wind power | Electricity | Now and developing |
| Hydrogen/fuel cells | Electricity | Now and developing |
| Solar photovoltaic | Electricity | Now and developing |
| Tidal power | Electricity | Now/limited scope |
| Wave power | Electricity | Medium-/long-term |
| Solar thermal | Electricity | Medium-/long-term |

Renewables are seen as a means whereby utilities can reduce various environmentally damaging emissions. Despite these important benefits, many utilities are reluctant to adopt renewables, citing the intermittent nature of renewables (such as wind and photovoltaics), which can lead to system imbalances. For example, the output from a wind turbine varies with the speed of the wind, while photovoltaics (PVs) only generate electricity when the sun is available and the output can vary depending upon the angle of the PV module with respect to the sun. As a result, connecting intermittent renewables with an existing electricity grid can be problematic, as the utility cannot accurately forecast when to expect electricity from the renewable source.

The global industry expanding new renewable energies is now investment on the order of $30 billion a year. This has made the new renewable industry a significant market player in some countries. Issues of market shares and market power are becoming increasingly significant, attracting the attention of traditional market players. Hydropower, biomass, biogas, bio-fuels, wind power, solar energy and geothermal energy are the major resources to provide Turkey with most of its renewable energy in the future. In this study, the policy, potential and barriers of these renewable energy sources are assessed for supplying the future needs of Turkey.

## 2. Renewable energy policy

Energy is recognized as a crucial element in a country development process. Energy constitutes one of the main inputs for economic and social development. In line with the increasing population, urbanization, industrialization, spreading of technology and rising of wealth, energy consumption is increasing. Energy consumption and consequently energy supply at minimum amount and cost is the main objective, within the approach of a sustainable development that support economic and social development and that have destructive impact on the environment at the minimum level. Turkey's energy policy is based on the following items:

- Meeting long-term demand using 2P and F (public, private, and foreign) capital.
- Privatization activities, especially accelerating privatization activities, in the energy sector.
- Taking into consideration supply costs of energy imports, especially oil and natural gas.
- Ensuring optimum development of all the indigenous energy sources.
- Ensuring sustainable operation of the energy utilizations.
- Ensuring rational use of total energy sources.
- Ensuring environmentally sound sustainable energy development programs causing minimum damage to the environment.
- Meeting demand as much as possible through domestic resources.
- Diversifying energy supplies and avoiding dependence on a single source or a country.
- Adding new and renewable sources (geothermal heat, solar, wind, etc.) as soon as possible to the energy supply system.
- Ensuring sufficient, reliable and economic energy supplies on time.
- Ensuring energy security of supply.
- Implementing measures for energy efficiency.
- Planning energy research and development activities to meet requirements for increasing energy demands
- Minimizing losses in energy production. transmission, distribution and consumption in the country.
- Protecting the environment and public health in the production of energy.

As basic strategy, improvement of domestic production by increasing efficiency of plants by rehabilitation, diversification of energy sources to secure fuel supply, accelerating the existing construction programs, initiation of new investments are chosen to achieve these energy policies. As Government's financial resources are not enough to achieve these objectives, accelerating of private investments is essential.

## 3. Renewable market conditions

Before looking at the likely economic performance of the different technologies, it is necessary to consider the characteristics of each and the impact that they may make on the energy market. Two important market conditions relate to (i) overall liberalization of the market, and (ii) the mechanisms that are applied to reflect concerns about energy supply security, industrial competitiveness, and environmental protection.

### 3.1. Hydropower

Turkey does not have enough primary energy sources such as petroleum and natural gas, but has and huge hydropower potential. Turkey's second largest energy source after coal is hydro. Hydroelectricity schemes fall into two major categories:

- Large schemes with generating capacities that, range from 5 MW to several GW. The use water from mountain lakes or reservoirs, held back by dams. The largest of the schemes represent major works of civil engineering in their construction, and they are operated by electricity utilities that feed the electricity into the grid.
- Small schemes of a few kW up to 5 MW. These do not normally involve reservoirs and dams, but rely on the flow of rivers and streams, often in hill or mountains terrain.

The Ministry of Energy and Natural Resources (MENR) hopes that hydro capacity will expand to 35,000 $MW_e$ by the year 2020. The government expects the construction of 332 more hydro plants in the long-term to make use of the potential remaining hydro sites. This would bring the number of hydro plants to 485, and add more than 19 GW of capacity to the hydro system. This increase in the hydro generating capacity includes the South-eastern Anatolia Project (GAP) that covers one-tenth (74,000 $km^2$) of Turkey's total land area, one of the largest hydro developments ever undertaken. Upon its completion, GAP will have an installed capacity of 7476 MW. The construction of all these new dams requires an investment of more than US$ 30 billion [4]. The hydro resources have the following advantages:

- It is obtained free of charge.
- It is a renewable source of energy.
- It is indigenous.
- It does not pollute the environment.
- Its operation cost is low.
- Reservoirs could have potential for irrigation projects and flood control.

In 2005, the total world production of hydroelectricity was around 2836 TWh. The outputs of the hydroelectricity from the most leading countries in Europe and Turkey are given in Table 2. Hydroelectricity is predicted to grow and the Utility Data Institute estimates that, over the next 10 years, 153 $GW_e$ of new capacity will be installed world-wide, i.e. about one-fifth of the expected total new generating capacity [6].

### 3.2. Domestic solar water heaters

Turkey lies in a sunny belt between 36°N and 42°N latitudes. The yearly average solar radiation is 3.6 $kWh/m^2$ day and average sunshine duration is 2640 h, corresponding to around 30% of the year. Solar energy potential in Turkey is showed in Table 3.

Solar energy technologies are not extensively used, except for solar water heaters (SWH). The domestic or industrial SWH is a simple system that comprises a water tank and a solar flat-plate

**Table 2**
Leading producers of hydroelectricity at end-2005, adapted from [5]

| Country | $MW_e$ | Percent of Europe total | Percent of domestic electricity | Country | $MW_e$ | Percent of Europe total | Percent of domestic electricity |
|---|---|---|---|---|---|---|---|
| Russia Federation | 45,700 | 19.2 | 22.17 | Portugal | 4,818 | 2.02 | 40.65 |
| Norway | 27,698 | 11.64 | 69.66 | Ukraine | 4,736 | 1.99 | 8.77 |
| France | 25,526 | 10.72 | 22.82 | Germany | 4,525 | 1.91 | 3.6 |
| Spain | 18,674 | 7.84 | 30.14 | Greece | 3,060 | 1.29 | 25.03 |
| Italy | 17,326 | 7.28 | 21.25 | Finland | 3,000 | 1.27 | 18.23 |
| Sweden | 16,100 | 6.77 | 47.98 | Serbia | 2,891 | 1.21 | 31.13 |
| Switzerland | 13,356 | 5.61 | 77.11 | Bulgaria | 2,874 | 1.2 | 30.39 |
| Turkey | 12,778 | 5.37 | 28.97 | Slovakia | 2,547 | 1.08 | 35.17 |
| Austria | 11,811 | 4.96 | 83.76 | Rest of Europe | 14,214 | 5.97 | – |
| Romania | 6,346 | 2.67 | 29.5 | Europe Total | 237,980 | 100 | – |

**Table 3**
Solar energy potential for seven regions of country

| Region | Radiation energy | Sunshine duration period | | | | |
|---|---|---|---|---|---|---|
| | Average ($kWh/m^2year$) | Maximum ($kWh/m^2year$) | Minimum ($kWh/m^2year$) | Average (h/year) | Maximum (h/month) | Minimum (h/month) |
| Southeast Anatolia | 1492 | 2250 | 600 | 3016 | 408 | 127 |
| Mediterranean | 1453 | 2112 | 588 | 2924 | 360 | 102 |
| Central Anatolia | 1434 | 2112 | 504 | 2712 | 381 | 98 |
| Aegean | 1407 | 2028 | 492 | 2726 | 371 | 96 |
| East Anatolia | 1395 | 2196 | 588 | 2694 | 374 | 167 |
| Marmara | 1144 | 1992 | 396 | 2528 | 351 | 88 |
| Black Sea | 1086 | 1704 | 408 | 1966 | 274 | 84 |

collector to heat the water. The solar collector is made of a series of thin black pipes that are insulated, through which water passes collecting the heat from the sun before entering the tank. To increase the temperature, systems are designed so that the water re-circulates through the collector until the desired temperature is achieved. New materials, larger collectors and quality improvements are being undertaken in this technology. Other uses of direct solar thermal energy are solar cookers, crop drying and for space heating. Turkey has a total installed capacity of 8.2 million $m^2$ collector area with a total energy production of 287,000 toe, as of 2001. In Turkey solar energy has a technical potential of 8.8 mtoe electricity generation and 26.4 mtoe heating capacity. The SWH industry, in Turkey, is well developed and main system produced is the thermosyphon type and consist of two flat plate solar collectors having an absorber area between 3 and 4 $m^2$, a storage tank with capacity between 150 and 200 l and a cold water storage tank, all installed on a suitable frame. SWH use is limited to supply of domestic hot water for about 19% of the housing stock. The daily consumption of hot water by a family of four persons between springs and autumn (for 9 months) can be estimated to be 80 l a at 60 °C, requiring about 1 $kWh_{thermal}$. Hence, the life cycle cost can be calculated to be €12 cents per kWh as compared to €15.5 cents/kWh, if electricity heating is used instead. The payback period would then be about 4.5 years in Turkey.

### 3.3. Photovoltaic system

Turkey has a total installed capacity of about 0.5 $MW_e$ for photovoltaic cells mostly in communication stations, fire observation stations, sea lighthouses, and highway lighting [4]. Germany has the most installed photovoltaic power with 1229 $MW_e$ in Europe and also approximately 84% of installed photovoltaic power of Europe is being in Germany, see Table 4. At present, Turkey does not have an organized commercial and domestic photovoltaic (PV) programme [7,8], because the government has no intention in PV technology. On the other hand, there is good potential for PV applications in the local market since the country is enormously suitable due to high rates of solar radiation and available land for PV applications. Installation costs of small PV systems (<5 kWh) in Turkey would be around 9 €/Wh installed. Life cycle cost analysis, based on a 10% net discount factor and a 20 year lifetime, could be around €52 cents per kWh. Under these circumstances, small PV systems would have no payback period within this lifetime.

### 3.4. Wind energy

Wind energy is the fastest growing energy source in the world and wind power is one of the most widely used alternative sources of energy today. It is a clean and renewable source of electricity [9]. With an annual average wind speed and power density of about 2.5 m/s and 25.8 W/$m^2$, respectively, the western, northern and south-eastern coasts of Anatolia have been identified as very favorable locations for wind power generation in Turkey. Technical wind potential of Turkey is given as 88,000 GW and the economic potential is estimated as 10,000 MW [10]. The current production status of wind energy projects in Turkey is between 727.96 and 817.96 MW [11].

A detailed wind speed assessment will have to be under taken before a more accurate assessment of wind potential can be made. The majority of wind energy projects are concentrated in the Aegean (16 projects) and Mediterranean regions (9 projects). The installed capacity of wind energy is expected to reach 600 MW by 2010 and 1000 MW by 2020. Theoretically, Turkey has 160 TW h a year of wind potential, which is about twice as much as the current electricity consumption of Turkey [12]. Wind farms are being built in various countries and are already making significant contributions to national energy supply. By the autumn of 2005, the total

**Table 4**
Photovoltaic power installed in Europe in 2005, adapted from [5]

| Country | $MW_e$ | Percentage of Europe total | Percentage of domestic electricity | Country | $MW_e$ | Percentage of Europe total | Percentage of domestic electricity |
|---|---|---|---|---|---|---|---|
| Germany | 1429 | 83.79 | 1.14 | Norway | 7.25 | 0.42 | 0.03 |
| Spain | 51.9 | 3.05 | 0.08 | Sweden | 4.23 | 0.25 | 0.01 |
| Netherlands | 50.77 | 2.98 | 0.25 | Finland | 4 | 0.23 | 0.02 |
| Italy | 34 | 1.99 | 0.04 | Denmark | 2.7 | 0.15 | 0.02 |
| France | 33.57 | 1.97 | 0.03 | Portugal | 2.28 | 0.13 | 0.02 |
| Switzerland | 26.3 | 1.55 | 0.15 | Turkey | 0.5 | 0.02 | 0.02 |
| Austria | 24 | 1.4 | 0.17 | Hungary | 0.1 | 0.01 | 0.01 |
| Luxembourg | 23.6 | 1.39 | 4.72 | Rest of Europe | 0.52 | 0.02 | – |
| United Kingdom | 10.9 | 0.65 | 0.01 | Europe total | 1705.63 | 100 | – |

**Table 5**
Wind power installed capacity in Europe in 2005, adapted from [5]

| Country | $MW_e$ | Percentage of Europe total | Percentage of domestic electricity | Country | $MW_e$ | Percentage of Europe total | Percentage of domestic electricity |
|---|---|---|---|---|---|---|---|
| Germany | 18,428 | 44.87 | 14.69 | Poland | 124 | 0.31 | 0.36 |
| Spain | 1,028 | 24.42 | 16.18 | Finland | 82 | 0.19 | 0.49 |
| Denmark | 3,129 | 7.62 | 22.94 | Ukraine | 72 | 0.17 | 0.13 |
| Italy | 1,639 | 3.99 | 2.01 | Luxemburg | 35 | 0.08 | 7 |
| United Kingdom | 1,565 | 3.81 | 2.05 | Estonia | 32 | 0.07 | 0.96 |
| Netherlands | 1,224 | 2.99 | 6.03 | Latvia | 25 | 0.06 | 1.17 |
| Portugal | 1,063 | 2.59 | 8.97 | Czech Republic | 22 | 0.05 | 0.14 |
| Austria | 819 | 1.99 | 5.8 | Turkey | 20 | 0.04 | |
| France | 723 | 1.77 | 0.65 | Hungary | 17 | 0.04 | 0.2 |
| Greece | 573 | 1.39 | 4.68 | Switzerland | 12 | 0.02 | 0.07 |
| Ireland | 496 | 1.21 | 11.11 | Russian Federation | 11 | 0.02 | 0.005 |
| Sweden | 493 | 1.21 | 1.47 | Rest of Europe | 279 | 0.68 | – |
| Belgium | 167 | 0.41 | 1.06 | Europe total | 41,078 | 100 | – |

**Table 6**
Geothermal energy in the world in 2005, top 10 producers of non-electric ($MW_{th}$) and electric ($MW_e$) power

| Country | $MW_{th}$ | Percentage of world total | Country | $MW_e$ | Percentage of world total |
|---|---|---|---|---|---|
| USA | 8,670 | 29.23 | USA | 2,564 | 28.4 |
| Sweden | 3,840 | 12.95 | Philippines | 1,978 | 21.9 |
| China | 3,687 | 12.43 | Mexico | 953 | 10.56 |
| Iceland | 1,804 | 6.09 | Italy | 810 | 8.96 |
| Turkey | 1,229 | 4.15 | Indonesia | 797 | 8.83 |
| Austria | 1,134 | 3.82 | Japan | 535 | 5.92 |
| Japan | 822 | 2.77 | New Zealand | 434 | 4.8 |
| Hungary | 694 | 2.33 | Iceland | 232 | 2.57 |
| Italy | 682 | 2.29 | Costa Rica | 163 | 1.8 |
| Switzerland | 582 | 1.96 | El Salvador | 151 | 1.67 |
| Rest of world | 6,524 | 21.99 | Rest of world | 414 | 4.59 |
| World total | 29,668 | 100 | World total | 9,031 | 100 |

world installed capacity was estimated to be about 59,335 $MW_e$, of which 41,078 $MW_e$ was located in Europe, see Table 5. Over the past few years, the rate of growth in Europe has been around 40% per annum, a rate equaled only by the cellular phone and computing industries.

Studies have estimated approximate costs for onshore wind-generated energy as a function of wind regime, based upon a new turbine of 850–1500 kW capacity, investment cost ranging between 900 and 1100 €/kW, O&M cost of about €1.2 cents/kWh over the turbine's 20 year lifetime and an annual discount rate of 7.5% based upon 2003 prices. At sites having low wind speeds (average wind speed of 5.4 $ms^{-1}$) the cost of electricity ranges from 6 to €8 cents/kWh. At good coastal sites (average wind speed of about 6.9 $ms^{-1}$), the cost of energy ranges between 4 and €5 cents/kWh [12].

### 3.5. Geothermal energy

The 10 countries with the greatest installed capacity for heat extraction are listed, in descending order, in Table 6 together with the 10 countries with the most installed capacity for geo-electricity generation. The production energy worldwide from aquifers in 2000 was about 15,145 $MW_{th}$ and 7974 $MW_e$ [13] and in 2005 was about 29,668 $MW_{th}$ and 9031 $MW_e$.

Turkey is the fifth richest country in the world [14] and 30 in Europe, see Table 7 in geothermal potential for its direct use.

It is located on the Alpine-Himalayan organic belt, having one eighth of the world's geothermal potential. Turkey has 170 geothermal fields over 400 °C temperature and around 1000 hot and mineralized natural self-flowing springs and they are located mainly on West, North-west and Central Anatolia. Turkey is ranked as fifth biggest geothermal energy user for heating and hot spring purposes after China, Japan, USA and Island [15]. Turkey's geothermal fields are more available to direct-use applications, since 95% of geothermal fields are low-medium enthalpy resources. Gross geothermal potential of Turkey is given as 31,500 $MW_{th}$, corresponding to 5 million residences heating whereas the economic potential for heating purposes is estimated to be 2843 $MW_{th}$ but the share of geothermal energy production, both for electrical and thermal uses is 1229 $MW_{th}$, see Table 8.

**Table 7**
Electricity generation and direct use of geothermal energy in Europe, adapted from [5]

| Country | $MW_{th}$ | Percentage of Europe total | Country | $MW_e$ | Percentage of Europe total |
|---|---|---|---|---|---|
| Sweden | 3,840 | 27.56 | Italy | 810 | 68.93 |
| Iceland | 1,804 | 12.95 | Iceland | 232 | 19.74 |
| Turkey | 1,229 | 8.82 | Russian Federation | 79 | 6.72 |
| Austria | 1,134 | 8.14 | Turkey | 20 | 1.71 |
| Hungary | 694 | 4.98 | Portugal | 18 | 1.54 |
| Italy | 682 | 4.89 | France | 15 | 1.28 |
| Rest of Europe | 4,549 | 32.66 | Austria | 1 | 0.08 |
| Europe total | 13,932 | 100 | Europe total | 1,175 | 100 |

**Table 8**
Capacities in geothermal utilization in Turkey (2006) [16]

| Geothermal utilizations | Capacity |
|---|---|
| District heating | 827 $MW_t$ |
| Balneological utilization | 402 $MW_t$ |
| Total direct use | 1,229 $MW_t$ |
| Power production | 20.4 $MW_e$ |
| Carbon dioxide production | 120,000 t/year |

**Table 9**
Some of Turkey's high enthalpy geothermal fields

| Geothermal field | Temperature (°C) | Geothermal field | Temperature (°C) |
|---|---|---|---|
| Denizli-Kizildere | 242 | Manisa-Salihli-Caferbeyli | 155 |
| Aydin-Germencik-Omerbeyli | 232 | Izmir-Seferihisar | 153 |
| Canakkale-Tuzla | 174 | Izmir-Balcova | 126 |
| Kutahya-Simav | 171 | Ankara-Kizilcahamam | 106 |
| Aydin-Salavatli | 162 | Afyon | 106 |

Some of the geothermal fields of Turkey are given in Table 9. Aydin-Germencik, Denizli-Kizildere, and theoretically Nevsehir-Acigol fields have the highest enthalpy among all and can be used both for electricity generation and district heating applications. These fields may be evaluated if the government offers the financial and/or institutional support that is required for successful development [17]. Electricity generation projections of Turkey are also 500 $MW_e$ from Germencik, Kizildere, Tuzla and several of the other fields by the year 2010 and 1000 $MW_e$ by 2020 [18].

### 3.6. Biomass

Biomass energy includes fuel wood, agricultural residues, animal wastes, charcoal and other fuels derived from biological sources, are used by approximately half of the world's population as cooking and/or heating fuel and currently accounts for about 14% of world energy consumption. Biomass is the main source of energy for many developing countries, providing more than 90% of the energy supply in some developing countries. Fuel wood and other biomass fuels are handled and combusted primarily by women, who are largely responsible for repetitive chores, such as cooking, and are often involved in any household industries. Women and children generally have the main responsibility for collecting fuel. It is estimated that Turkey has a theoretical gross biomass potential of 135–150 mtoe/year, and a theoretical net potential of 90 mtoe/year. But the economical potential is given as 25 mtoe/year. The total recoverable bio-energy potential is estimated to be about 16.92 mtoe as given in Table 10. The estimate is based on the recoverable energy potential from the main agricultural residues, livestock farming wastes, forestry and wood processing residues and municipal wastes.

The production of electricity from the generated methane gas through a 40% efficiency process, would yield a unit cost of €1.5 cents. O&M, which must include gas purifications prior to

**Table 10**
Total recoverable bio-energy potential in Turkey [19]

| Type of biomass | Energy potential (ktoe) |
|---|---|
| Dry agriculture residue | 4,560 |
| Moist agriculture residue | 250 |
| Animal waste | 2,350 |
| Forestry and wood processing residues | 4,300 |
| Municipality wastes and human extra | 1,300 |
| Firewood | 4,160 |
| Total bio-energy | 16,920 |

burning, would add €0.5 cents; gas collection and power transmission losses and safe disposal of small amounts of hazardous waste from gas purification would add €0.2 cents. Real cost which must include initial waste collection is €2.8 cents.

## 4. Current situation of renewable energies

Renewable energies are just starting to play a significant role in the world's energy market while the oil sector is still expected to be biggest player. In 2005, 86.4% of global energy production came from non-renewable sources like oil, natural gas, coal, and nuclear power. Renewables, consisting primarily of large hydropower plants and traditional fuels such as firewood and charcoal which are primarily used in the Third World accounted about 13%. Other renewable sources such as biomass, geothermal, wind and solar power totaled only 0.6% [20]. This low share of renewables in global energy production could be explained by analyzing the barriers that renewable energy face today. However, it is expected that a significant global increase in the use of renewable energies will occur in the future [21]. This increase can be understood by analyzing the main driving forces pushing renewable energy development.

## 5. Applications barriers of renewable energy in Turkey

The major barrier to use of renewable energy is the fact that all such sources have low energy intensity per unit area. Four major barriers have to be overcome to increase the use of renewable energy in the market. These are economic barriers, cost of technologies, financing issues and scientific and technical barriers. Each of these barriers is given below.

Economic barriers; economic barriers are assumed to the primary barriers to a broader introduction of renewable energy technologies. These factors include the cost of renewable technologies and their resultant electricity; difficulties in obtaining financing for renewable technologies, the failure to include externalities in the cost of generating electricity; and the money and interests already investment in existing infrastructure and technology.

Cost of technologies; while renewable energy technologies require no fuel and their operation and maintenance cost (O&M) cost are generally low, the upfront capital cost of renewable are relatively high per unit of capacity installed. These high capital cost is considered to be one of the major barriers to greater use of renewable technologies. Higher production costs of renewable energy might be attributed to two main aspects. First, renewable energy has higher capital costs than fossil-fuelled systems. This might be reduce the access to funding, i.e. higher financial risks. Besides, most of the tax systems tend to penalize capital-intensive renewable energy investments. Second, external environmental and social costs of fossil fuels have been ignored by markets. These costs include pollution, greenhouse gas emissions, and even military expenditures to defend overseas oil supplies.

Financing issues; another critical factor in the development and use of renewable technology is financing. Much of the cost of generating electricity with oil, coal and gas is the cost fuel; this investment is made and recouped in relatively small increments over many years. With renewable technologies, however, the initial capital outlay is large and must be recovered slowly over a period of many years, making it difficult for renewable to attract capital. Thus, investment in renewable energy technologies is discouraged at the outset.

Scientific and technical barriers, scientific and technical barriers are also blamed for stalling large-scale adoption of renewable energy technologies. Policy environments; one of the most significant policy barriers for renewable links back to economic factors; the impact of government R&D funding and subsidies on the cost of various resources and technologies. Successful commercialization of renewable energy sources has been hindered by competition in the electricity markets, due to barriers such as [22];

- High capital cost associated with building the necessary infrastructure to promote clean energy sources.
- Initial transactions cost associated with reaching environmentally conscious consumers.
- The inability of clean energy technologies to penetrate the electricity markets, despite their long-term cost-effective power technologies.
- Failure to quantify the economic development benefits and national economic security provided by renewables.

### *5.1. Hydropower*

The main disadvantage of hydropower is its initial capital cost. Furthermore, hydro dams raise some social and environmental concerns. These concerns include; effects of changing river flows on ecosystem regimes, inundation of extensive land areas necessitating relocation of residents and loss of agricultural land, silt deposition and impact on certain sensitive species. Environmental Impact Assessment (EIA) and Social Impact Assessment (SIA) are required before undertaking such hydropower developments. Mitigation measures identified during those assessments could reduce the social and environmental impacts. Mini hydro and small-scale hydro dams could avert some of social and environmental problems. In addition, they could reduce power shortage vulnerability during drought seasons experienced in large hydro plants.

Hydropower's fuel sources is renewable, it is available on site (no mining, transporting, etc. required), and no combustion is required. It also has the large disadvantage that generation depends on precipitation, which varies from year to year. These environmental implications are different from fossil fuel cycles. The main implications to be considered with hydroelectricity are the land and water ecosystem impacts associated with construction and operating hydro electric dams, the cost of power, and the renewable nature of the fuel supply. Hydropower releases no $CO_2$ directly, but is less reliable than fuel plants due to droughts.

### *5.2. Solar water heaters*

Prices for solar water heater models have been coming down recent years in Turkey. Good quality evacuated tube absorbers are currently selling at around €900 for a 150 l system. On the other hand, a better informed public is now evaluating costs, maintenance and installation more critically, which should lead to a higher customer satisfaction, signally lacking to date. Domestic water heating by electricity accounts for 20–30% of the annual

electricity consumption. Since the sun does not always shine, electricity storage or back up is required; this increases costs significantly and can lead to additional environmental problems.

### 5.3. Photovoltaic systems

At the present time, there are several barriers to the widespread use of photovoltaic systems. These barriers are include its higher cost of power generation compared to conventional sources, lack of financing, market barriers related to the lack of large scale product manufacturing and distribution, lack of support infrastructures, import tariffs and institutional barriers that favor the use of traditional energy sources. Institutional include the lack of widespread understanding of PV systems engineering and integration by contractors, architects and engineers; and lack of system performance familiarity [23]. The photovoltaic system modules must not have a significant visual impact. There has not been any proposal for building-integrated PV system in Turkey.

The innovation system for PV is focused around two broad areas: "conventional PV", based on crystalline silicon and existing thin-film technologies, and 'novel PV', based on novel photoactive materials and systems, such as organic solar cells. Policy support for market creation, through capital grants programmes, pro-active support and building and planning regulations is seen as critical to the future development of the Turkish PV industry, together with the need for a stable, long-term policy framework. The Demonstration Programme of capital grants is seen as an important step forward in this regard. In the case of PV for niche applications the fallowing areas are weak in implementation currently:

- Lack of financing mechanisms.
- Policy mechanism.
- User mechanism service network.

The major environmental problem associated with photovoltaic systems is the use of toxic chemicals, such as cadmium sulfide and gallium arsenide, in their manufacture. Since these chemicals are highly toxic and persist in the environment for centuries, disposal and recycling of the materials in inoperative cells could become a major problem. The worldwide trend in PV commercialization is to utilize policy incentives that significantly improve the economics and marketability of PV to bring prices down enough to expand from niche markets to broad consumer markets. The goal is to create a sustainable industry that will drive down prices through volume and competition. Although bringing down the cost of PV modules is important. There could be other policy measures that enhance the utility and effectiveness of existing units, and also encourage further adoption of the technology in niche areas.

### 5.4. Wind turbines

Operating at an ideal location, a turbine with a capacity of at least 500 kW can run at maximum 30% efficiency and produce most commercially wind-generated electricity of 1.3 million kWh year$^{-1}$ [24]. A 500-kW capacity turbine requires 13,700 ha of land, an initial investment of approximately US$ 500,000, and an annual operating cost of US$ 40,500 [23]. The estimated cost of electricity generated by such a system is US$ 0.07 per kWh, with an energy input–output ratio of 1:5 during the 30-year life of the system [25]. Wind turbines have not yet been the subjects of serious planning legislation in Turkey. The Turkish industry is currently a limited player in the manufacture of turbines and other components. The scale and cost of a wind farm will almost certainly require private investment, with its inevitable demand for an attractive rate of return. Offshore wind turbines development raises further barriers that include [26]:

- Intrusion into areas of shallow water staked-out for other economic activities.
- Higher construction and connection costs.
- Increased cost of work directed to solutions of problems associated with the interaction of a wind farm with a small grid.
- The environmental impacts of wind energy production include site selection of the wind turbines in or near the flyways of migrating birds and wildlife refuges, electromagnetic interference with television and radio signals within 2–3 km of large installations, and noise of rotating blades [25].
- Wind farms should be located away from wildlife refuges and residential areas. Since the turbines themselves occupy only approximately 2% of the area, most of the land can be used for a type of farming such as vegetables, nursery stock, and cattle that is practical without the use of the heavy equipment between the turbines.

Wind energy is an intermittent resource, meaning that sometimes there could be no power generated at all. This tendency makes wind energy unsuitable for continuous applications. In cases where continuous power is required or there is a need to switch on the power at a specific time or day, a backup generator is necessary. This is the case with electricity generation using wind energy—a back up generator supplies electricity when the wind is low or not available. The wind energy is renewable and does nor produces green house gas, hence is environmentally friendly. However, windmills could be a source of scenic and noise pollution. They could also harm bird flocks using their path. The main barriers to the wide application of wind energy would be initial investment cost of installation and a backup facility due to intermittent nature of the wind and speeds. A thorough wind speed database is required for analysis to determine the possibility of installation, size of the windmill to produce required and economics of the windmill installation. It is a resource to be considered whenever speed and the economics allow.

The number of attractive sites for wind turbines is limited since they must have high wind during most hours of the year. Humans cannot control wind speed, requiring backup power when the wind does not blow. While wind turbines emit no pollutions, the life cycle of these turbines does require materials and emit pollutions, as well as use land. The most important current objections seem to be objections to placing the turbines in their best locations, highly visible such as the tops of ridges or mountains or in the ocean. In case of wind, the following areas exhibit a potentially weak link;

- Infrastructural support.
- Social compatibility.
- Lack of trained O&M technicians.
- Lack of distribution mechanisms.
- Lack of support infrastructure.
- Tradition of failed projects.

### 5.5. Geothermal energy

During construction, drilling and well-testing stages, noise pollution could be very scary to animals and human beings. Air pollution could be another environmental effect caused by geothermal energy development. This is due to direct releases of geothermal steam during all stages of development and releases of non-condensable gases during plant operation.

The exploration and exploitation of geothermal resources is influenced by a number of factors, varying from one to the next. Besides environmental considerations described above, there other factors that include technical and scientific problems, economic and financial concerns, human resource availability, and legal and institutional constraints. Technical and scientific problems encompass all the problems connected with exploration, fluid extraction and subsequent exploitation of geothermal fluids for power generation and/or direct heat. The second category (economic and financial) takes the high cost of capital investment into consideration and addresses the issue of risk.

Potential environmental problems with geothermal energy include water shortages, air pollution, and waste effluent disposal. The wastes produced in the sludge include toxic metals such as arsenic, boron, lead, mercury, radon, and vanadium [27]. Water shortages are an important limitation in arid regions. Geothermal systems produce hydrogen sulfide, a potential air pollutant; however, this product could be processed and removed for use in industry [28]. Overall, the environmental costs of geothermal energy appear to be minimal relative to those of fossil fuel systems. However, geothermal energy sources are suggested to be deflectable and decline over 40–100 years globally [29].

### 5.6. Biomass

For heat and electricity production, there are existing projects, mainly using combustion. This is a commercial technology, in which the Turkish has leading technology players, and the technology and market risk are relatively low. Policy support has been and is directed at combustion systems, but has tended to favor potentially more efficient and cleaner advanced Technologies such as gasification and pyrolysis. Innovation is focused on the development of these technologies, which are at the demonstration stage but are commercial in niche markets. For transport fuel production, there is some Turkey R&D, but little commercial activity.

The biomass fuel cycle has near-zero net emissions of $CO_2$ since $CO_2$ are fixed by the plants as they grow. The land area to replace a significant portion of the electricity currently generated by coal limits the use of biomass. In case of biomass, the following links are clearly weak,

- Resource compatibility.
- User support.
- Needs assessment.
- Using wastes for fuel may degrade soil quality.
- Sugar plantations, sawmills, etc. often owned by rural elite.
- Could results in competition between land uses for feed/fuel.

It is difficult to collect large quantities of biomass wastes due to their disperse nature. The availability of some types of biomass is seasonal. In addition annual productions of most biomass fluctuate from year to year depending on climatic conditions. Biomass is also difficult and costly to transport. The costs of biomass wastes fluctuate widely, depending crop the productions and economic condition.

## 6. Conclusions

Renewables, especially hydropower, can play a significant role in satisfying the future energy need in Turkey. The present renewable market conditions, for instance in Turkey, may not be a good guide to the future since the wholesale price of electricity is remarkably high at present, corresponding to the gas and oil price. We are examined some reasons why many renewable energy projects have failed in Turkey:

- Many renewable energy projects in country used premature technologies which were still under-research
- The design of many projects did not allow sufficient, long-term maintenance.
- Many renewable energy projects were either demonstration projects, or for other reasons not replicated.
- Renewable energy technologies are often simply too expensive to be used in country, where financial resources are limited.

The effectiveness comes from the uniqueness of renewable energy technologies with respect to following aspects:

- Being a low cost technology.
- Modern energy services must be meet multiple social needs.
- Renewable energy technologies are the key element to overcome the stalemate in international climate negotiations.
- Energy policy markers have to make choices, all electricity generating options have environmental, social, and economic consequences, and the optimum decision has to be made in particular situations.

## References

[1] Ward DJ, Bahaj AS, James PAB. Economics of future energy systems. In: World renewable energy congress IX; 2006.
[2] Bukarica V, Vrhovcak MB. Renewable energy policy in Croatia: current status and future activities. In: World renewable energy congress IX; 2006.
[3] Dell RM, Rand DAJ. Clean energy. In: RSC clean technology monographs; 2004.
[4] Evrendilek F, Ertekin C. Assessing the potential of renewable energy sources in Turkey. Renewable Energy 2003;28:2303–15.
[5] World Energy Council (WEC). Turkish National Committee: Ankara; 2006. www.dektmk.org.tr.
[6] International Energy Agency. Key World Energy Statistics from the IEA, 2003 ed., Paris, France: International Energy Agency; 2003.
[7] Kaygusuz K. Renewable and sustainable energy use in Turkey: a review. Renewable Sustainable Energy Rev 2002;6:339–66.
[8] Ocak M, Ocak Z, Bilgen S, Keles S, Kaygusuz K. Energy utilization, environmental pollution and renewable energy sources in Turkey. Energy Convers Manage 2004;45:845–64.
[9] Ogulata RT. Energy sector and wind energy potential in Turkey. Renew Sust Energy Rev 2003;7:469–84.
[10] Ozturk HK, Yilanci A, Atalay O. Past, present and future status of electricity in Turkey and share of energy sources. Renew Sust Energy Rev 2007;11:183–209.
[11] Aras H. Wind energy status and its assessment in Turkey. Renew Energy 2003;28:2213–20.
[12] EWEA. Wind energy-the facts, in collaboration with the European Commission's Directorate General for Transport and Energy (DG TREN), www.ewea.org; 2005 [consulted June 12, 2005].
[13] Lund JW, Freeston D. World-wide direct uses of geothermal energy 2000. Geothermics 2001;30:29–68;
Huttrer GW. The status of world geothermal power generation 1995–2000. Geothermics 2001;30:7–27.
[14] Demir F. A failure story: politics, society and financial liberalization in Turkey. The paths of retransformation in the post-liberalization era; 2002. http://www.econturk.org.
[15] State Institute of Statistics (DIE); 2005. www.die.gov.tr.
[16] Geothermal energy in Turkey; 2006. www.jeotermaldernegi.com.
[17] Hepbasli A. Current status of geothermal energy applications in Turkey. Energy Sources 2003;25:667–77.
[18] Gokcen G, Ozturk HK, Hepbasli A. Turkey's geothermal fields suitable for power generation. Energy Sources 2004;26:441–51.
[19] Kaygusuz K. Sustainable development of hydropower and biomass energy in Turkey. Energy Convers Manage 2002;43:1099–120.
[20] EIA/DOE. International Energy Outlook; 2002. www.eia.doe.gov/oiaf/ieo.
[21] Elliot D. Renewable Energy and Sustainable Future. Futures 2000;32:261–74.
[22] International Energy Agency (IEA). Report: towards a sustainable energy future. Paris, France: OECD/IEA; 2001.
[23] Adamantiades D, et al. The World Bank's solar initiative, strategy for development of renewable energy projects. Adv Solar Energy 1998;12 [Chapter 1].

[24] American Wind Energy Association (AWEA). Wind energy and climate change (October 20, 2002; www.awea.org/pubs/factsheets/climate.pdf).

[25] Keller J. The environmental impacts of wind energy developments. Town Plann Rev 1990;91:139–54.

[26] Farrugia RN, Fsadni M, Mallia EA, Yousif C. Barriers and incentives for the widespread application of renewable energy in Malta. World Renewable Energy Congress IX. Florence, Italy, 19–25 August.

[27] US Department of Energy–Energy Information Administration. Annual energy outlook 2002 with projections to 2020. Washington, DC: US Department of Energy–Energy Information Administration; 2001.

[28] Bradley RL. Renewable energy: not cheap, not green. Washington, DC: Cato Institute; 1997.

[29] Cassedy ES. Prospects for sustainable energy. New York: Cambridge University Press; 2000.